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1977 EMISSIONS INVENTORY FOR SOUTHEASTERN VIRGINIA

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16 Abstract

An emissions inventory is a necessary prerequisite for regional air quality simulation modeling. Such an inventory for a 1977 summer workday was compiled for the Peninsula and Tidewater, Virginia, jurisdictions of Norfolk, Chesapeake, Portsmouth, Virginia Beach, Hampton, Newport News, York County, James City County, and Williamsburg. The 1 km^2 Universal Transverse Mercator coordinate system was used, and the methods of compilation are outlined.

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SUMMARY

An emissions inventory is a necessary prerequisite for regional air quality simulation modeling. Such an inventory for a 1977 summer workday was compiled for the Peninsula and Tidewater, Virginia, jurisdictions of Norfolk, Chesapeake, Portsmouth, Virginia Beach, Hampton, Newport News, York County, James City County, and Williamsburg. The 1 km^2 Universal Transverse Mercator coordinate system was used, and the methods of compilation are outlined.

INTRODUCTION

Regional tropospheric air pollution modeling is performed in an attempt to simulate the time variation of species concentrations in and around an urban area. Several types of models are used for simulation: smog chamber, trajectory, and combined transport-chemical kinetics. Smog chamber models usually treat only chemical kinetics while the latter two types of models include both kinetics and transport. Contributions to the time variation of species concentrations in the urban area include industrial and residential anthropogenic emissions, entrainment, and transport into the urban area of pollutants generated from upwind sources. Therefore, a prerequisite for modeling any urban area is an emissions inventory which includes emissions from both the urban and the surrounding areas.

The methods used to compile an emissions inventory suitable for air quality simulation modeling in Southeastern Virginia are described below. The Southeastern Virginia area is comprised of nine jurisdictions: the cities of Norfolk, Chesapeake, Portsmouth, Virginia Beach, Hampton, Newport News, and Williamsburg, and the counties of York and James City (see fig. 1). The area was chosen for modeling studies to support a remote sensor development and validation program being conducted at NASA Langley Research Center -- the South-Eastern Virginia Urban Plume Study (SEV-UPS). Attention has been focused on this geographic region because it is frequently in violation of the ozone standard established by EPA. In addition, the region is interesting geographically since portions of it are bordered by the Atlantic Ocean, Chesapeake Bay, and several rivers. The vehicular traffic is rather heavy with a small amount of mass transportation available, and the industrial activity is light; the predominant employers are the military, shipbuilders, and harbor-related industries such as petroleum storage facilities.

The emissions inventory was compiled following, as closely as possible, procedures outlined by EPA (ref. 1) and the Virginia State Air Pollution Control Board (VSAPCB) (ref. 2) and was tabulated on a 1 km^2 grid using the Universal Transverse Mercator (UTM) coordinate system. The UTM coordinates of a block are defined by the coordinates of the northwest corner of that block. Separate compilations were performed for each source type, industrial point sources, residential area sources, and vehicular area sources to facilitate yearly updating. Hourly emissions for a typical summer day in 1977 were tabulated for CO, total hydrocarbons (THC), nitrogen oxides (NOX), SO_2, and total solid particulates (TSP). The values for NOX represent the combined emissions for NO and NO_2. To the extent possible, the numbers obtained in this inventory were checked against those tabulated by the National Emissions Data Service (NEDS) and the VSAPCB (ref. 2). The methods of compilation and distribution of emissions are described below.

VEHICLE EMISSIONS

The emissions factors for vehicle travel in a given calendar year are influenced by several factors: travel fraction, vehicle type, altitude, speed of travel, and chemical species being emitted. The travel fraction (TF) is the percentage of vehicles of a given model year which are traveling on the roads in the calendar year for which an emissions inventory is being calculated (ref. 1); e.g., the fraction of 1976 model cars traveling in 1977. Vehicle types are separated into groups according to weight classification and engine type: light-duty gasoline-powered vehicles (automobiles and motorcycles - LDV), two types of light-duty trucks (LTI <6000 lb. and LTII <8500 lb.), heavy-duty gasoline-powered trucks (HTI) and heavy-duty diesel trucks (HTII). The yearly vehicle miles traveled (VMT) by vehicle type for each jurisdiction were obtained from the Virginia State Department of Highways; the percentages of vehicle types in each jurisdiction were then calculated using this information. All calculations discussed here are for low-altitude, non-California vehicle travel.

Emissions factors, based on the speed of travel, can best be assigned when vehicle travel is distributed according to primary and secondary roadways. Yearly VMT and summer-traffic counts for primary roads by jurisdiction were obtained from the Virginia State Department of Highways. The yearly VMT was distributed throughout the year based on travel days per month to obtain the VMT for a typical summer workday. The yearly VMT were not evenly distributed throughout the year, because the summer tourist industry increases the VMT/day by 20 percent relative to winter travel; such an increase is reflected in increased primary roadway traffic counts. The distribution of yearly VMT by month is shown in table I.

Primary VMT were obtained directly from traffic counts and distributed on a 1 km^2 grid using the UTM coordinate system. The distribution was performed by locating the traffic counting stations for primary roads on maps and measuring the miles of primary road per square kilometer. Multiplication of the miles by the traffic count yielded primary VMT for each roadway per square kilometer for a summer day. All primary VMT were then summed to obtain the total primary VMT (by jurisdiction). Secondary VMT per day were obtained by

subtraction of the primary VMT from the total VMT and distributed in the coordinate system using estimated secondary street densities.

Emissions in grams per mile of travel were calculated following a procedure prescribed by EPA (ref. 1). The amount of emissions (or emissions factor, EF) for a given vehicle type, ℓ, and a species, j, is a function of the travel fraction, TF_ℓ, and is obtained from

$$EF_{j\ell} = \sum_{\substack{\text{model}\\\text{years}}} (TF_\ell)(\text{emissions}_{j\ell}) \ .$$

The emissions were obtained from standard EPA tables for vehicles traveling at 20 mph. Variations from 20 mph were obtained by calculating a speed correction factor, SCF, which is a function of the posted speed limit, k,

$$SCF_{jk\ell} = \sum_{\substack{\text{model}\\\text{years}}} (TF_\ell)(SCF_{jk\ell}) \ .$$

A composite emissions factor for all vehicle types based on the percentage of each vehicle type can then be obtained. For CO, crankcase hydrocarbons, and exhaust hydrocarbons, the equation is (ref. 1)

$$\text{Composite } EF_{jk} = \sum_{\substack{\text{vehicle}\\\text{type}}} (\%\ \text{type})(EF_{j\ell})(\exp[SCF_{jk\ell}])$$

while for vehicle NOX emissions

$$\text{Composite } EF_{jk} = \sum_{\substack{\text{vehicle}\\\text{type}}} (\%\ \text{type})(EF_{j\ell})(SCF_{jk\ell})$$

is used. No vehicle emissions data were listed by EPA for SO_2 or TSP; therefore, the VSAPCB values (ref. 2) of 0.23 grams per mile for SO_2 and 0.59 grams per mile for TSP were used.

Tables II and III list the emissions factors by vehicle type and the speed correction factors for CO, NOX, and hydrocarbons. Separate emissions factors are used to describe exhaust and crankcase hydrocarbon emissions whereas the same speed corrections factors are used for both types of hydrocarbon emissions. An intermediate check on the correctness of the calculations of speed correction factors is that the 20 mph value should equal 1.0. This check is valid since the emissions factors are calculated for a speed of 20 mph. It is interesting to note that as speed increases, emissions of CO and HC (in grams per mile) decrease while NOX emissions increase. This fact does not imply that less CO and HC are emitted by a vehicle traveling faster, but only that since the rate of travel is faster, less time is spent by the vehicle in a given mile of roadway. NOX emissions increase as the speed of travel increases.

The composite emissions factors for primary VMT were calculated by assuming a speed of 45 mph for vehicle travel and using percentages of vehicle types which were tabulated by jurisdiction. Primary roads were determined from maps, and primary VMT were obtained using traffic counts. From these data, the percentages of primary and secondary VMT were obtained and are listed in table IV. The sources of the differences in percentage of primary VMT for the cities of Hampton and Newport News (the Peninsula cities), and for Norfolk, Chesapeake, Portsmouth and Virginia Beach (the Tidewater cities), are twofold: (1) either many roads on the Peninsula were assumed to be primary roads; or, (2) the speed of travel on the Peninsula's primary roads was less than 45 mph.

In order to calculate emissions for travel on secondary roads, an average composite emissions factor for all vehicle travel was first calculated by dividing the VMT per year into the VSAPCB value for tons of a species emitted per year. Since the average emissions factor is a sum of emissions due to both primary and secondary VMT,

$$\text{Average } EF_{jk} = (\text{Primary } EF_{jk})\ (\%\ \text{Primary VMT}) +$$

$$(\text{Secondary } EF_{jk})\ (\%\ \text{Secondary VMT})\ ,$$

the secondary emissions factor can be obtained. Composite emissions factors for primary and secondary travel by jurisdiction are listed in table V. Again, it can be seen that the emissions factors for Hampton and Newport News are higher than those for the Tidewater area for the reasons previously stated.

An additional source of vehicle hydrocarbon emissions which must be included is evaporative loss during the filling of automotive and service station tanks. VSAPCB hydrocarbon emissions factors of 11.67 lb./1000 gallons gasoline for filling automotive tanks and 8.3 lb./1000 gallons gasoline for filling service station tanks were used. The total amount of gasoline was estimated using the VMT for each city and a factor of 15 miles per gallon of gasoline (ref. 2). The resultant evaporative losses of hydrocarbons during the filling of tanks are shown in table VI and were distributed by total travel miles per square kilometer.

One source of difficulty encountered in distributing vehicle emissions was the lack of complete information about the percentages of vehicle types and the hydrocarbon exhaust and crankcase emissions in York and James City Counties. Information about the total automobile hydrocarbon emissions was obtained for the counties from the VSAPCB emissions inventory for 1977; the hydrocarbon loss due to filling was subtracted from the total, and the exhaust to crankcase hydrocarbon emissions were obtained using an average percentage (from all other cities) of exhaust emissions of 64.69 percent. The difficulty with respect to lack of a breakdown of percentages of vehicle types was overcome by using the same percentages that were used for Newport News and Hampton.

OTHER EMISSIONS SOURCES

Other emissions sources that were included in the inventory are discussed separately below. They include industrial point sources and area sources such as residential solid waste disposal, surface coating and dry cleaning, aircraft, vessels, and railroads. Residential fuel combustion was neglected since the inventory was compiled for a summer day.

Industrial Sources

An industrial emissions inventory for a typical summer day in 1977 was compiled by the Region VI VSAPCB and used in this inventory. It included all types of industrial emissions and the hours of operation of each industry per day.

Residential Solid Waste Disposal

Emissions attributed to solid waste disposal were computed using VSAPCB emissions factors for incineration and open burning, and are based on population. An assumption of 10 percent open burning in the counties and 1 percent open burning in the cities was made. The VSAPCB emissions factors include an addition to the residential emissions to account for the fact that approximately 10 percent of the commercial and institutional sources were not identified as industrial point sources. The residential solid waste emissions are listed in table VII and were distributed using the secondary street densities.

Dry Cleaning and Surface Coating Operations

Hydrocarbon emissions due to the evaporation of solvents used in dry cleaning and residential surface coating operations were calculated using VSAPCB emissions factors. Surface coating operations primarily involve the application of paint, varnish, lacquer, or paint primer for decorative or protective purposes. Since the emissions factors are proportional to population, the emissions were distributed on the grid using secondary street densities which are also a reflection of population density. Totals by jurisdiction are shown in table VIII.

Aircraft and Vessels

Emissions from aircraft and vessels were calculated using the most recently available emissions factors (1975 factors) and the procedures outlined by the VSAPCB.

Vessel emissions were based on the numbers of gallons of distillate oil, residual oil and gasoline used, and on where the fuel was used--inport or underway. They are listed in table IX.

Aircraft emissions were based on the number of landing and takeoff cycles of each aircraft type (military, civil, and commercial) and were distributed uniformly over the jurisdictions. The emissions are shown in table X.

Railroads

Emissions from railroads were calculated using VSAPCB emissions factors and the miles of railroad track per jurisdiction. The actual number of railroad miles traveled was obtained through the use of the 1977 VSAPCB emissions inventory and an appropriate scale factor for each jurisdiction. Total railroad emissions for each jurisdiction are shown in table XI. The emissions were distributed by track miles.

RESULTS AND DISCUSSION

The combined daily emissions for all species for a summer workday in 1977 are listed in table XII. The major contributor of CO emissions was vehiclar activity; with the exceptions of power plants and oil refineries, emissions of CO from point sources were negligible. In contrast, contributions to total hydrocarbon and NOX emissions from vehicles and point sources were comparable while SO_2 and solid particulate emissions were derived chiefly from point sources.

Maps of the jurisdictions in Tidewater and the Peninsula, which were computer-generated using the UTM coordinate system, are shown in figures 2 and 3, respectively. Using this coordinate system and separate tabulations for vehicle and other area and point source emissions, combined emissions density maps for each species and area were generated and are shown in figures 4 through 13. The maps were generated by setting the largest emissions value for each species equal to 999. Therefore, a unit of density on the maps varies with the species: for CO, a unit of density corresponds to 249699 grams; for hydrocarbons, 30000 grams; for NOX, 25000 grams; for SO_2, 63000 grams; and for solid particulates, 13565 grams.

The vehicular activity is best represented by examining the CO density maps (figs. 4 and 5). An interstate highway, which runs from the lower right to upper left corners of the Peninsula map (fig. 5), is easily located. In addition, the large vehicular activity associated with the urban areas of Hampton, Newport News (fig. 5), and Norfolk (fig. 4) is seen.

Hydrocarbon and NOX emissions receive approximately equal contributions from point and area sources. The only noteworthy feature of the density maps (figs. 6, 7, 8, and 9) is the ability to distinguish concentrated urban areas.

The emissions of SO_2 and solid particulates are derived primarily from industrial activity. Large quantities of emissions are associated with heavy industry and power-generating facilities which are point sources. As a consequence, the emissions density maps for SO_2 and TSP (figs. 10 through 13) show high emissions concentrations located in single 1 km^2 blocks rather than more widely distributed densities that were seen for CO, NOX, and hydrocarbons.

CONCLUSIONS

An emissions inventory for a typical summer workday in 1977 was compiled for the Southeastern Virginia region. The UTM coordinate system was used to facilitate use of the inventory in regional air quality simulation modeling. Separate compilations of emissions from vehicles, other area sources, and industrial point sources were made to aid in the yearly update of the inventory. The combined emissions inventory may be obtained from the authors upon request.

REFERENCES

1. U. S. Environmental Protection Agency: Supplement No. 8 for Compilation of Air Pollutant Emission Factors, Third Ed. (Including Supplements 1-7). AP-42, Suppl. 8 (May 1978); ibid: Mobile Source Emission Factors. EPA-400/9-78-005 (March 1978).

2. Commonwealth of Virginia, State Air Pollution Control Board: Emission Inventory for the Year 1977 (May 1979).

TABLE I. - DISTRIBUTION OF YEARLY VMT BY MONTH

Month	Days/Month	Fraction Traveled	Travel Days
January	31	1.0	31
February	28	1.0	28
March	31	1.0	31
April	30	1.1	33
May	31	1.1	34.1
June	30	1.2	36
July	31	1.2	37.2
August	31	1.2	37.2
September	30	1.1	33
October	31	1.1	34.1
November	30	1.0	30
December	31	1.0	31
Total	365		395.6

TABLE II. - EMISSIONS FACTORS (g/mile) BY VEHICLE TYPE

	Vehicle Type				
Species	LDV	LTI	LTII	HTI	HTII
CO	59.225	63.833	78.351	25.890	30.264
HC(exhaust)	4.975	5.327	7.724	269.035	4.420
HC(crankcase)	1.988	2.191	3.531	2.920	0.0
NOX	3.246	3.280	5.433	10.839	20.624

TABLE III. - SPEED CORRECTION FACTORS BY VEHICLE TYPE

Speed (mph)	Species	Vehicle Type LDV	LTI & II	HTI	HTII
5	CO	3.691	3.796	1.368	2.497
	HC	3.402	3.449	3.187	1.836
	NOX	0.900	0.945	0.867	1.570
20	CO	0.984	0.986	1.000	1.000
	HC	0.985	0.986	1.000	1.000
	NOX	1.006	1.008	0.992	1.000
25	CO	0.806	0.816	0.793	0.795
	HC	0.809	0.825	0.747	0.853
	NOX	1.089	1.101	1.032	0.931
40	CO	0.487	0.502	0.532	0.503
	HC	0.511	0.527	0.403	0.606
	NOX	1.256	1.263	1.160	0.945
45	CO	0.453	0.465	0.518	0.509
	HC	0.474	0.487	0.360	0.566
	NOX	1.293	1.298	1.201	1.027

TABLE IV. - VEHICLE TRAVEL FOR A SUMMER DAY BY JURISDICTION

City	Total VMT($\times 10^{-5}$)	Primary VMT VMT($\times 10^{-5}$)	%	Secondary VMT VMT($\times 10^{-5}$)	%
Norfolk	53.435	29.162	54.57	24.272	45.43
Chesapeake	21.927	9.518	43.41	12.409	56.59
Portsmouth	13.207	5.543	41.97	7.664	58.03
Virginia Beach	43.591	17.657	40.51	25.934	59.49
Hampton	18.641	14.549	78.05	4.092	21.95
Newport News	22.984	16.792	73.06	6.192	26.94
York County	8.289	4.159	50.17	4.130	49.83
James City County[a]	6.638	4.309	64.91	2.329	35.09

[a]Includes Williamsburg

TABLE V. - COMPOSITE VEHICLE EMISSIONS FACTORS BY JURISDICTION

City	VMT/year ($x10^{-8}$)	Species	VSAPCB Emissions (T/year $x10^{-3}$)	Emissions Factors (g/mile)		
				Average	Primary	Secondary
Norfolk[a]	17.61563	CO	87.445	45.074	28.133	65.423
		HC_x[b]	7.672	3.955	2.497	5.706
		HC_c[b]	4.030	2.077	0.971	3.407
		NOX	8.102	4.176	4.716	3.528
Chesapeake[a]	7.22869	CO	34.949	43.900	28.129	55.997
		HC_x	3.082	3.871	2.494	4.928
		HC_c	1.656	2.080	0.971	2.931
		NOX	3.330	4.183	4.678	3.803
Portsmouth[a]	4.35409	CO	22.251	46.402	28.129	59.618
		HC_x	1.949	4.064	2.494	5.200
		HC_c	0.998	2.081	0.971	2.884
		NOX	1.972	4.112	4.678	3.703
Virginia Beach[a]	14.37042	CO	70.152	44.326	28.140	55.347
		HC_x	6.180	3.905	2.494	4.866
		HC_c	3.296	2.083	0.972	2.839
		NOX	6.568	4.150	4.661	3.802

TABLE V. - Continued

City	VMT/year ($x10^{-8}$)	Species	VSAPCB Emissions (T/year $x10^{-3}$)	Emissions Factors (g/mile) Average	Primary	Secondary
Hampton[a]	6.14548	CO	26.610	39.317	27.364	81.817
		HC_x	2.384	3.522	2.460	7.300
		HC_c	1.401	2.070	0.970	5.981
		NOX	2.959	4.372	4.776	2.934
Newport News[a]	7.57709	CO	32.902	39.428	27.364	72.145
		HC_x	2.944	3.528	2.460	6.424
		HC_c	1.727	2.069	0.970	5.051
		NOX	3.645	4.368	4.776	3.260
York County[c,d]	2.73273	CO	10.842	36.025	27.364	44.745
		HC_x	0.961	3.193	2.460	3.931
		HC_c	0.525	1.744	0.970	2.523
		NOX	1.307	4.343	4.776	3.907
James City County[c,d,e]	2.18834	CO	10.432	43.285	27.364	72.736
		HC_x	0.947	3.929	2.460	6.646
		HC_c	0.517	2.145	0.970	4.319
		NOX	1.270	5.270	4.776	6.184

[a]Data from Road Vehicle Transportation Emissions
[b]HC_x = Hydrocarbon exhaust emissions; HC_c = Hydrocarbon crankcase emissions
[c]Data from VSAPCB Emissions Inventory for the Year 1977
[d]Same vehicle type percentages as Hampton and Newport News
[e]Includes Williamsburg

TABLE VI. - EVAPORATIVE LOSSES OF HYDROCARBONS DURING THE FILLING OF TANKS BY JURISDICTION

City	THC Loss (g/day x 10^{-5})
Norfolk	32.297
Portsmouth	7.983
Chesapeake	13.253
Virginia Beach	26.347
Hampton	11.267
Newport News	13.892
York County	5.010
James City County[a]	4.012

[a]Includes Williamsburg

TABLE VII. - RESIDENTIAL SOLID WASTE EMISSIONS BY JURISDICTION

		Emissions (grams/day x10^{-4})				
Jurisdiction	Population	CO	THC	NOX	SO_2	TSP
Norfolk	278188	51.51	17.87	0.95	0.41	8.15
Chesapeake	100650	18.64	6.47	0.34	0.15	2.95
Portsmouth	108513	20.09	6.97	0.36	0.16	3.18
Virginia Beach	221375	40.99	14.23	0.75	0.32	6.49
Newport News	143538	26.58	9.22	0.49	0.21	4.20
Hampton	138063	25.57	8.87	0.47	0.20	4.04
York County	41474	12.49	4.36	0.48	0.12	2.12
James City County	22938	6.91	2.41	0.27	0.06	1.17
Williamsburg	10275	1.90	0.66	0.03	0.01	0.30

TABLE VIII. - HYDROCARBON EMISSIONS FROM DRY CLEANING AND

SURFACE COATING BY JURISDICTION

City	Population	Hydrocarbons (grams/day x10^{-4}) Surface Coating	Dry Cleaning
Norfolk	278188	276.82	69.20
Chesapeake	100650	100.15	25.04
Portsmouth	108513	107.98	26.99
Virginia Beach	221375	220.28	55.07
Newport News	143538	142.83	35.71
Hampton	138063	137.38	34.35
York County	41475	15.48	10.32
James City County	22938	8.56	5.71
Williamsburg	10275	3.83	2.56

TABLE IX. - VESSEL EMISSIONS BY JURISDICTION

City	Emissions (grams/day x10^{-4})				
	CO	THC	NOX	SO_2	TSP
Norfolk	360.21	119.41	63.93	220.91	25.37
Chesapeake	0.00	0.00	0.00	0.00	0.00
Portsmouth	28.36	10.45	62.44	220.16	23.88
Virginia Beach	0.00	0.00	0.00	0.00	0.00
Newport News	474.90	155.98	32.09	131.85	16.92
Hampton	158.71	52.74	12.69	15.42	1.49
York County	118.41	39.06	3.73	8.46	1.24
James City County[a]	262.95	86.32	2.49	3.98	1.24

[a]Includes Williamsburg

TABLE X. - AIRCRAFT EMISSIONS BY JURISDICTION

City	Emissions (grams/day x10^{-4})				
	CO	THC	NOX	SO_2	TSP
Norfolk	911.98	656.25	140.55	54.48	277.37
Chesapeake	102.74	17.91	3.73	0.99	3.98
Portsmouth	10.45	1.74	0.25	0.00	0.50
Virginia Beach	423.40	388.08	79.85	31.84	166.43
Newport News	314.44	170.65	36.82	13.68	68.91
Hampton	268.42	239.31	49.26	19.65	102.24
York County	0.00	0.00	0.00	0.00	0.00
James City County[a]	485.34	439.82	90.55	36.07	188.57

[a]Includes Williamsburg

TABLE XI. - RAILROAD EMISSIONS BY JURISDICTION

City	Emissions (grams/day x10^{-4})				
	CO	THC	NOX	SO_2	TSP
Norfolk	25.62	1.84	72.64	11.19	4.97
Chesapeake	32.34	2.34	91.79	14.18	6.22
Portsmouth	9.95	7.21	26.61	4.48	1.99
Virginia Beach	10.45	7.46	29.60	4.48	1.99
Newport News	4.48	3.23	12.69	1.99	0.75
Hampton	3.98	2.74	11.19	1.74	0.75
York County	5.22	3.73	14.68	2.24	0.99
James City County[a]	1.49	0.99	3.98	0.75	0.25

[a]Includes Williamsburg

TABLE XII. - COMBINED DAILY EMISSIONS OF CO, THC, NOX, SO_2 AND TSP BY SOURCE TYPE

Species	Area[a]	Emissions (grams/summer day) Vehicles	Other Area Sources	Point Sources	Total
CO	TDW	5.89×10^8	2.09×10^7	6.18×10^7	6.72×10^8
	PEN	2.27×10^8	2.20×10^7	2.58×10^8	5.07×10^8
THC	TDW	8.25×10^7	2.22×10^7	2.34×10^7	1.28×10^8
	PEN	3.56×10^7	1.66×10^7	2.50×10^7	7.72×10^7
NOX	TDW	5.47×10^7	5.45×10^6	3.14×10^7	9.15×10^7
	PEN	2.55×10^7	2.76×10^6	2.57×10^7	5.40×10^7
SO_2	TDW	3.02×10^6	4.32×10^6	1.08×10^8	1.15×10^8
	PEN	1.31×10^6	3.95×10^5	9.24×10^7	9.41×10^7
TSP	TDW	7.75×10^6	5.35×10^6	3.35×10^7	4.66×10^7
	PEN	3.37×10^6	4.03×10^6	6.59×10^6	1.40×10^7

[a]TDW = Tidewater; PEN = Peninsula

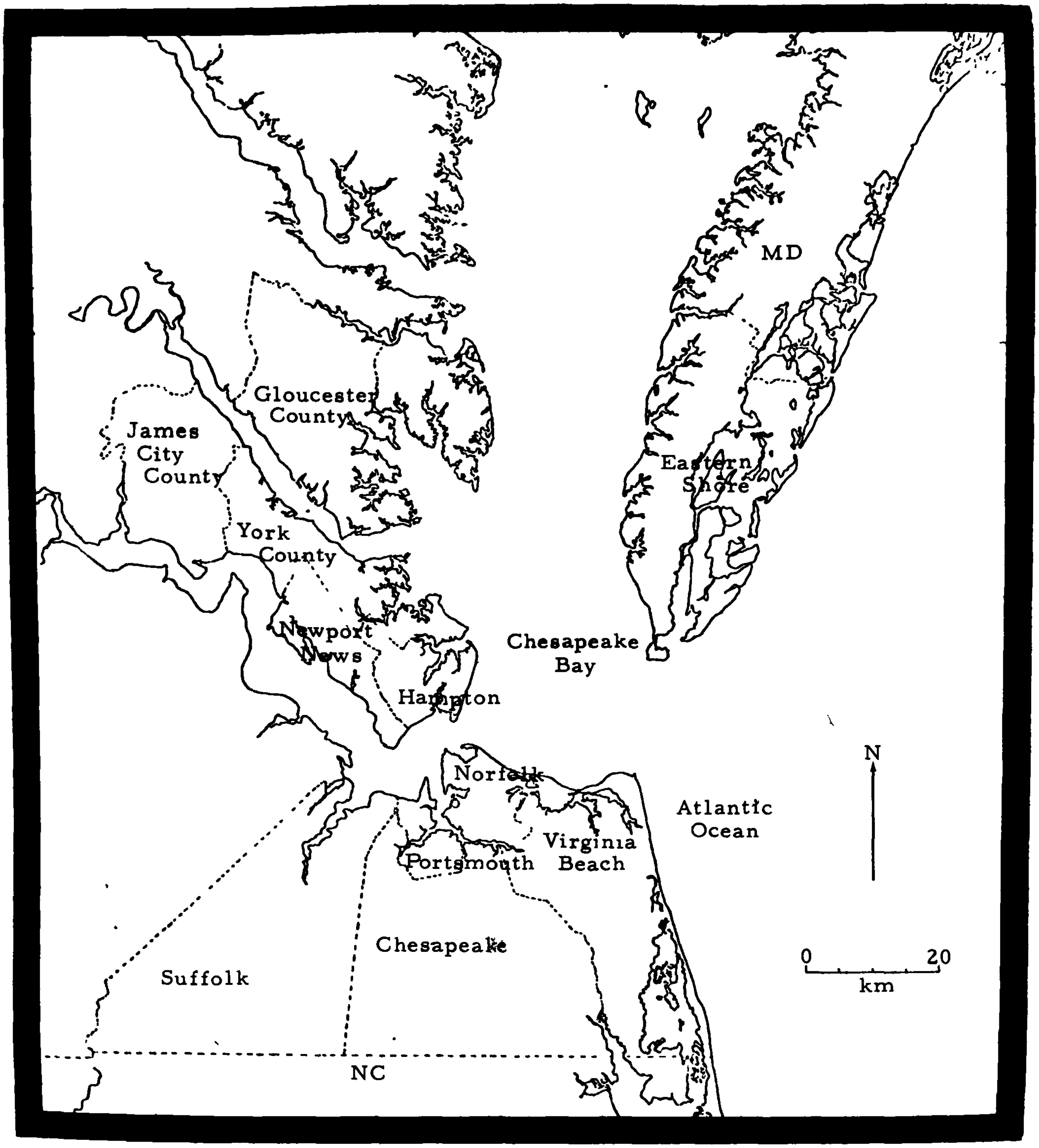

Figure 1. - Map of Southeastern Virginia

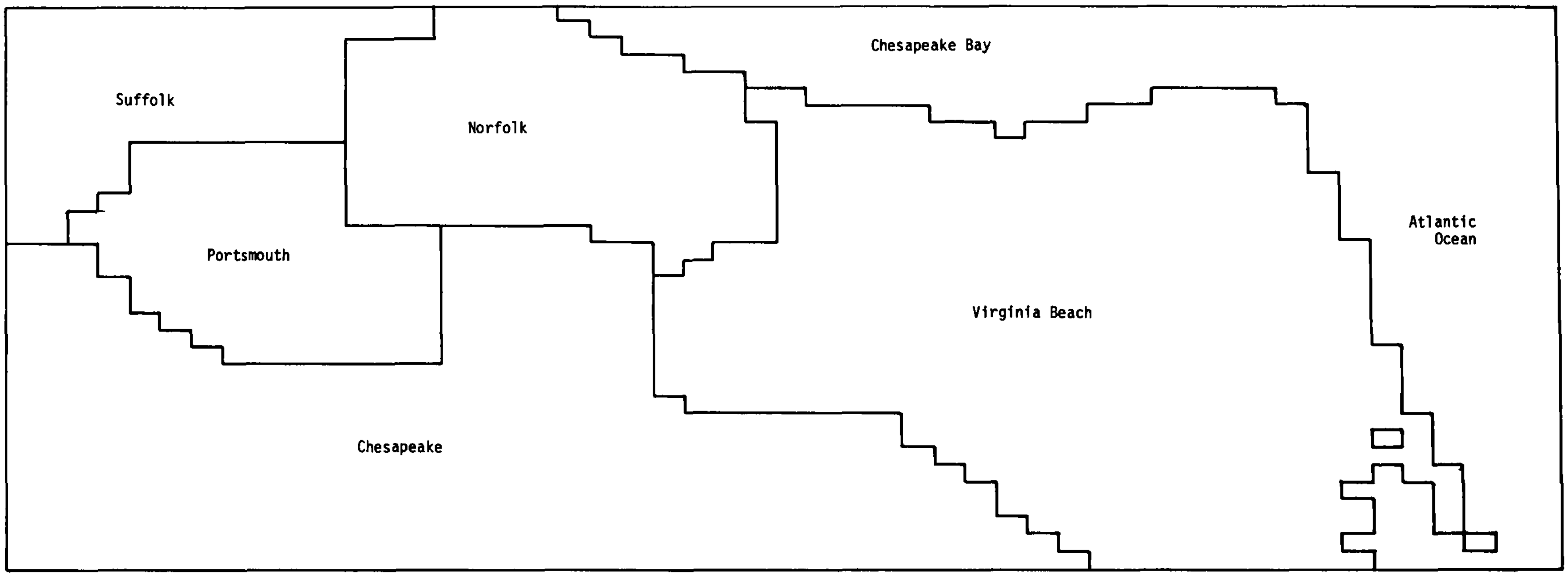

Figure 2 - Computer-generated map of Tidewater, Virginia

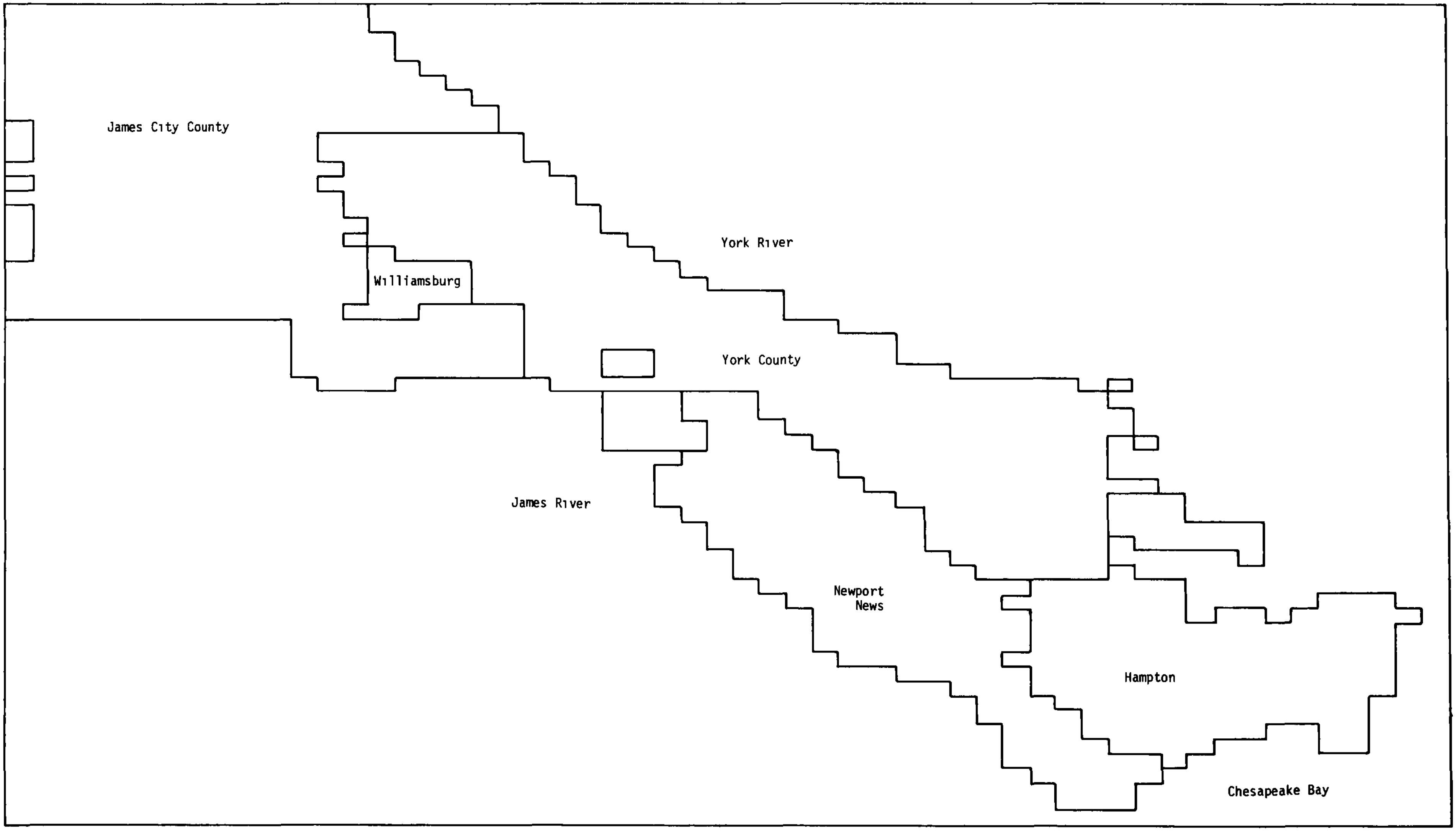

Figure 3 - Computer-generated map of Peninsula, Virginia

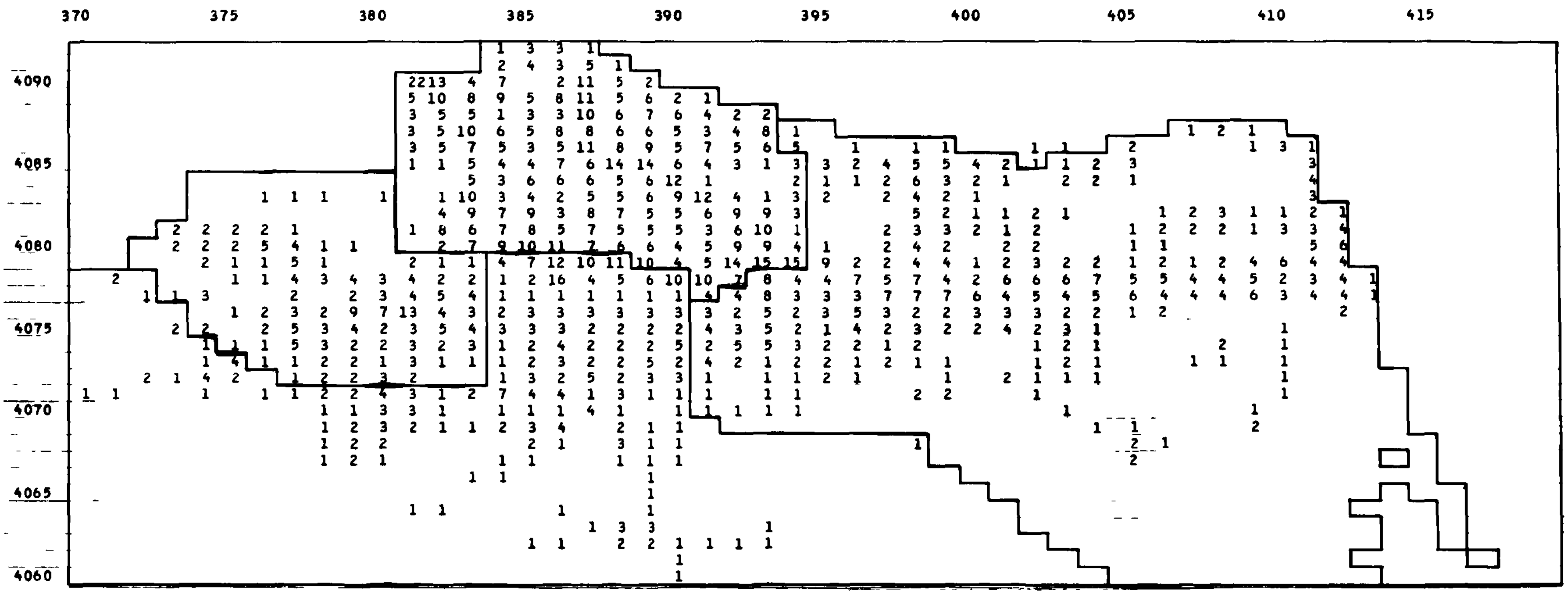

Figure 4 - Daily summer emissions of CO in Tidewater, Virginia Each unit corresponds to 249699 grams

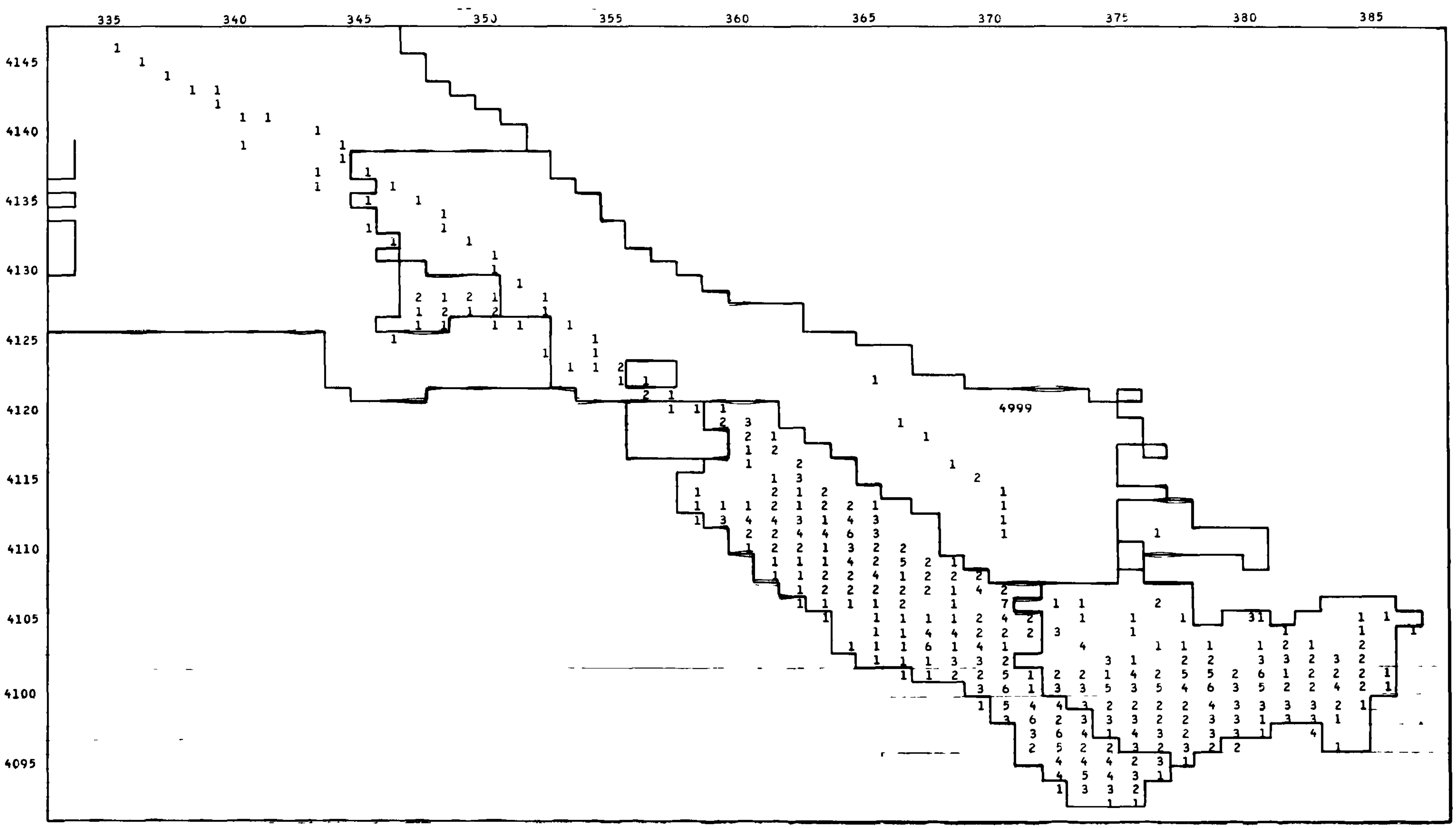

Figure 5 - Daily summer emissions of CO in Peninsula, Virginia   Each unit corresponds to 249699 grams

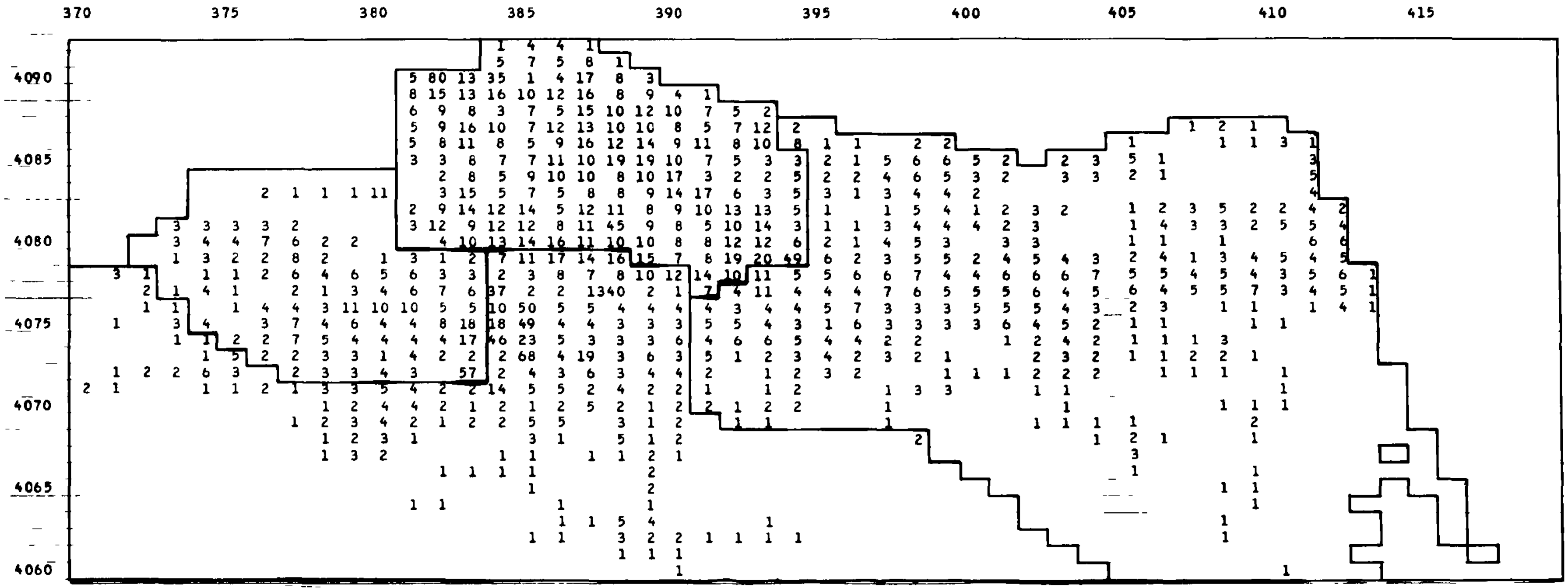

Figure 6 - Daily summer emissions of total hydrocarbons in Tidewater, Virginia Each unit corresponds to 30000 grams

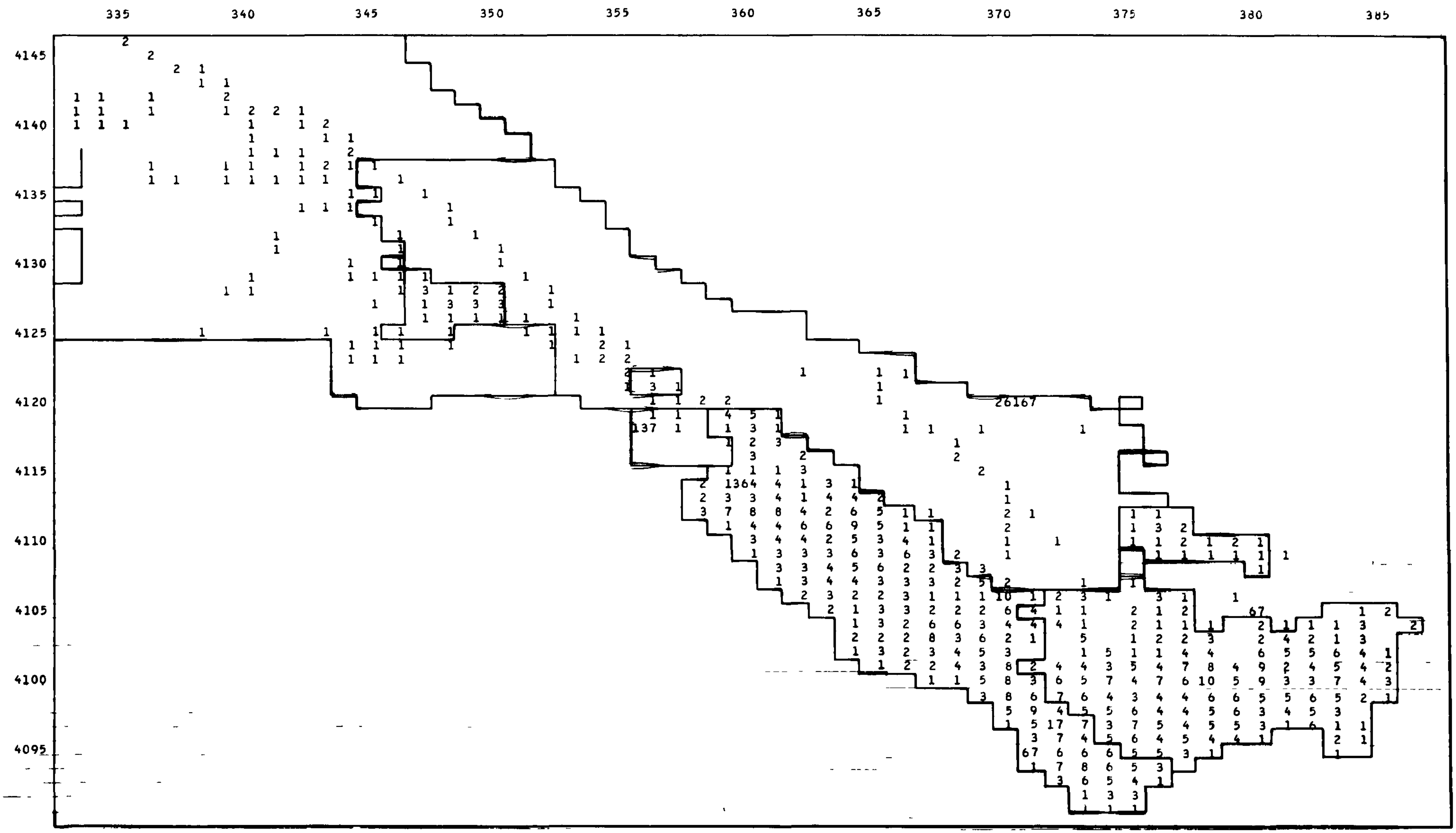

Figure 7 - Daily summer emissions of total hydrocarbons in Peninsula, Virginia Each unit corresponds to 30000 grams

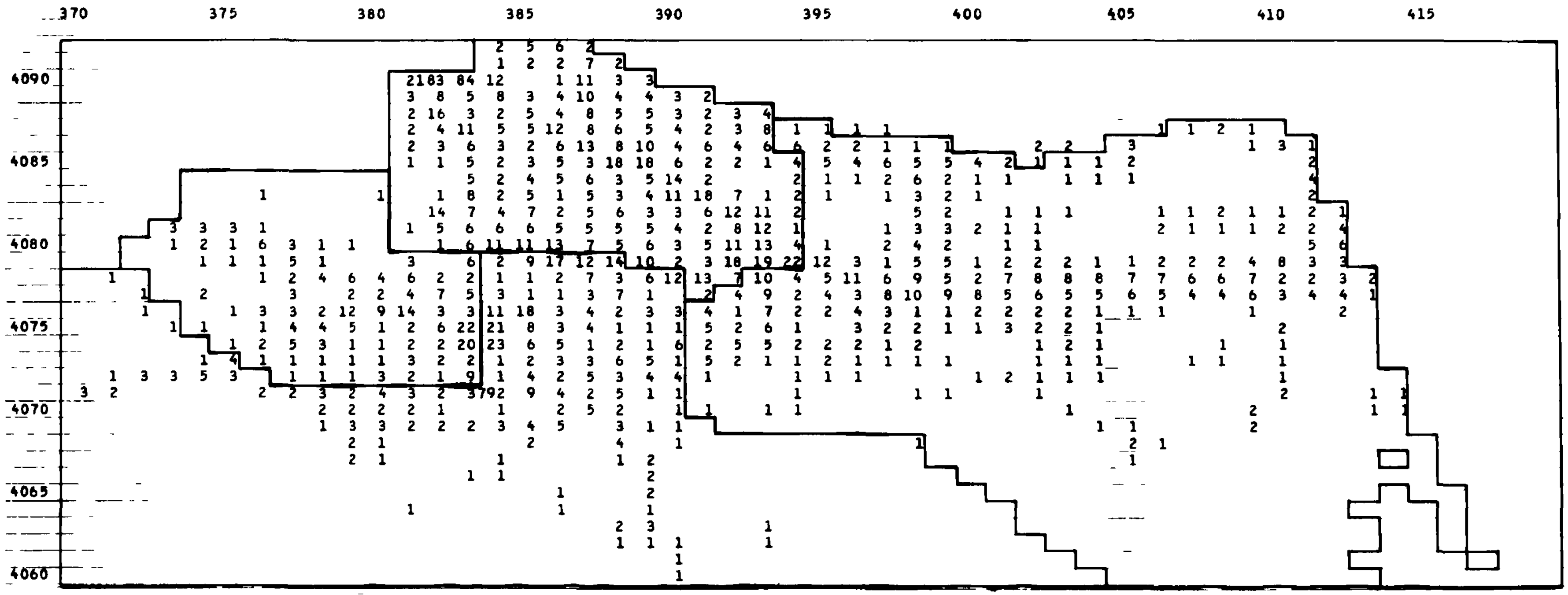

Figure 8 - Daily summer emissions of nitrogen oxides in Tidewater, Virginia Each unit corresponds to 25000 grams

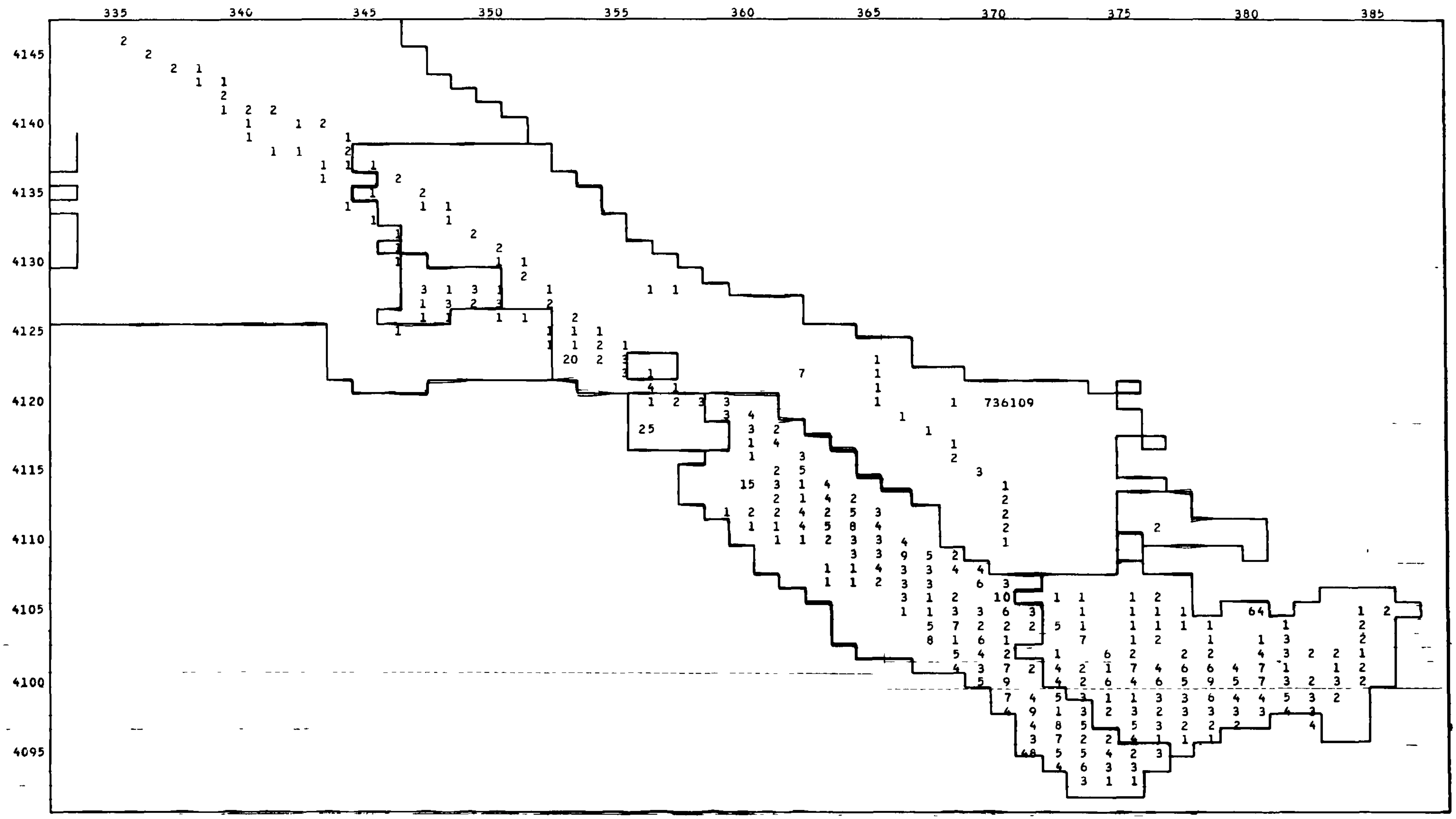

Figure 9 - Daily summer emissions of nitrogen oxides in Peninsula, Virginia Each unit corresponds to 25000 grams

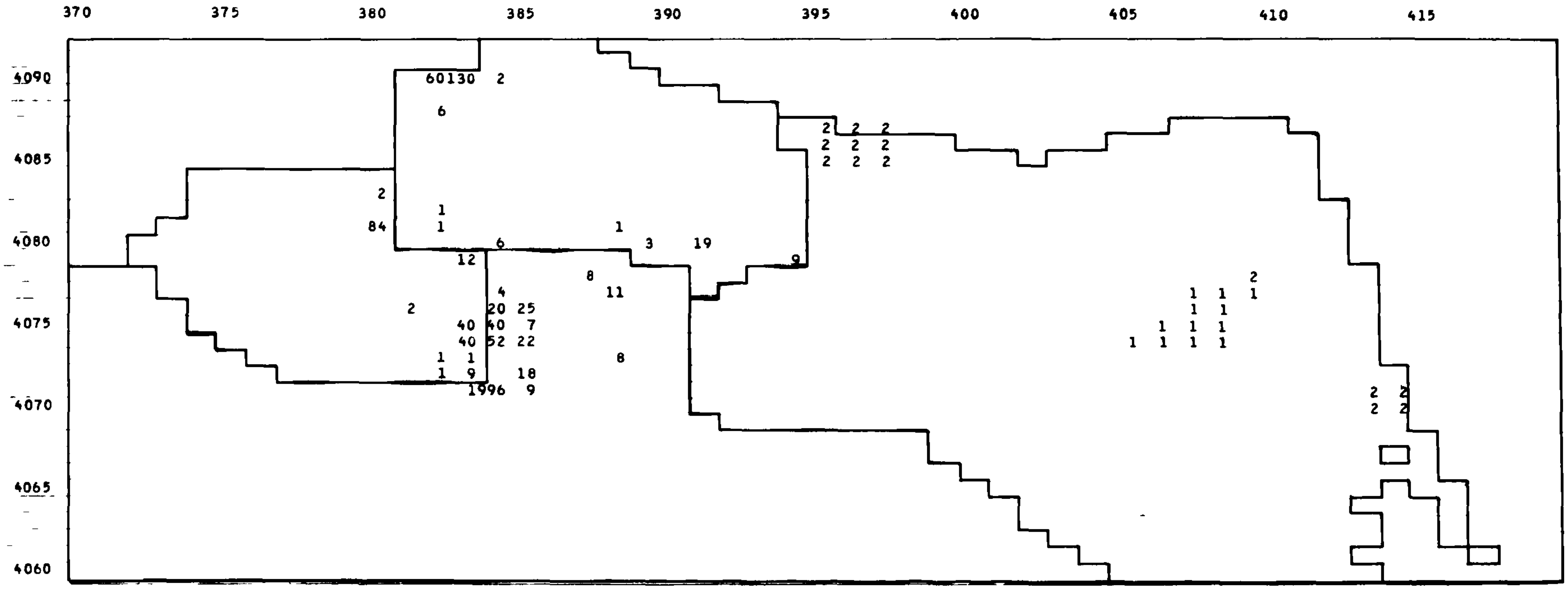

Figure 10 - Daily summer emissions of SO_2 in Tidewater, Virginia Each unit corresponds to 63000 grams

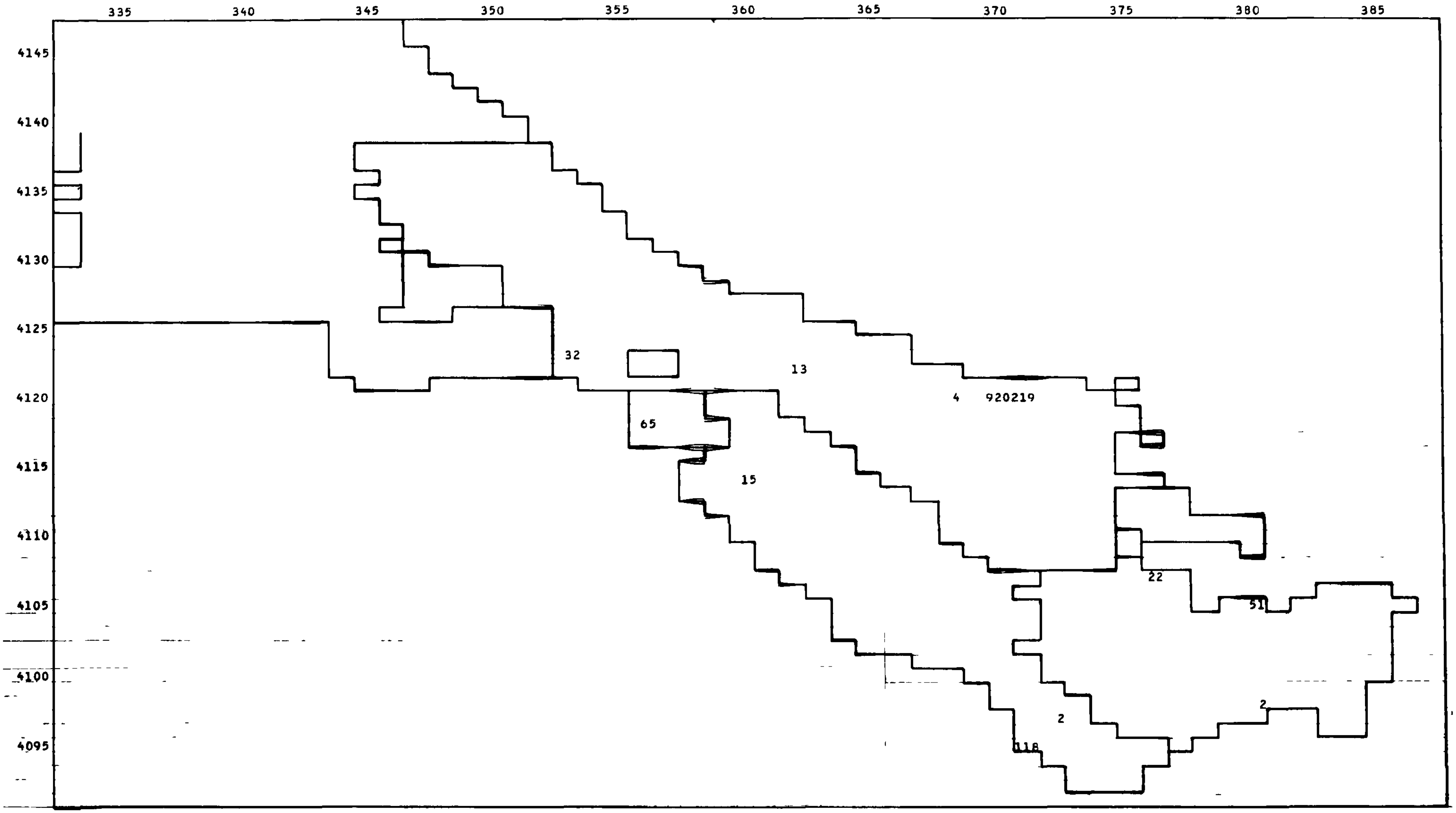

Figure 11 - Daily summer emissions of SO_2 in Peninsula, Virginia Each unit corresponds to 63000 grams

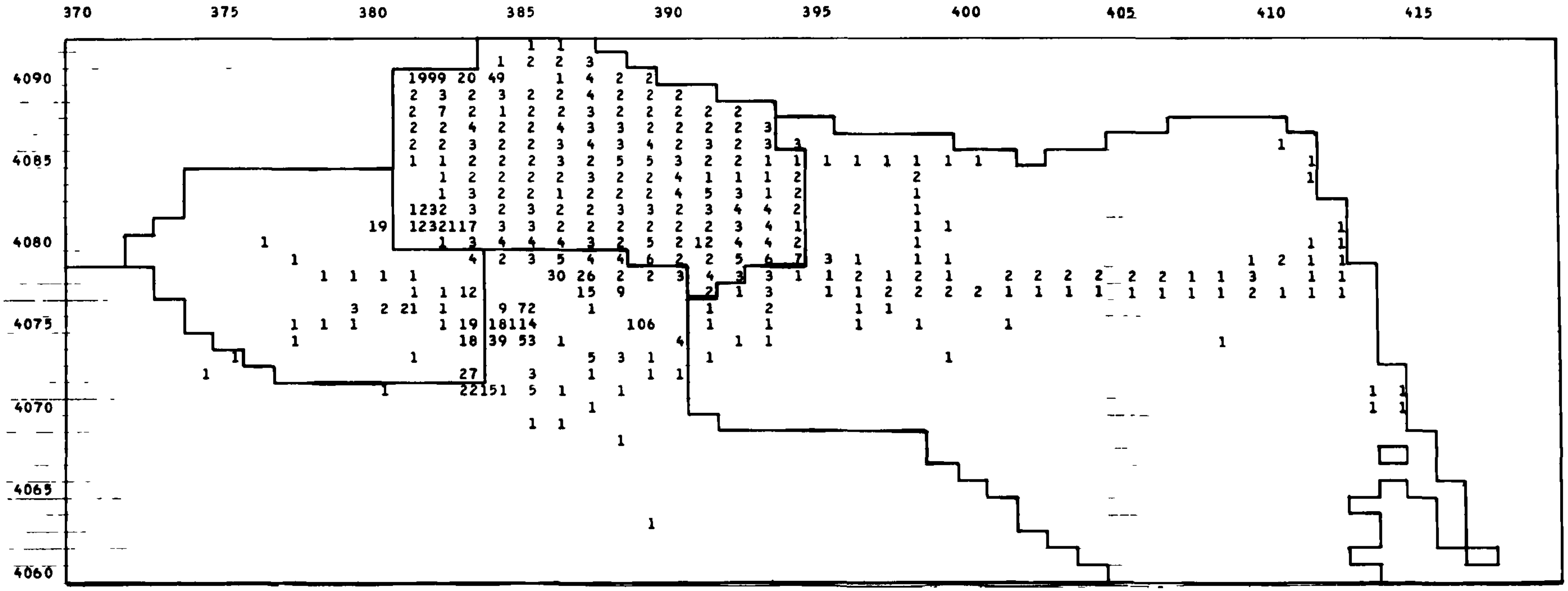

Figure 12 - Daily summer emissions of solid particulates in Tidewater, Virginia Each unit corresponds to 13565 grams

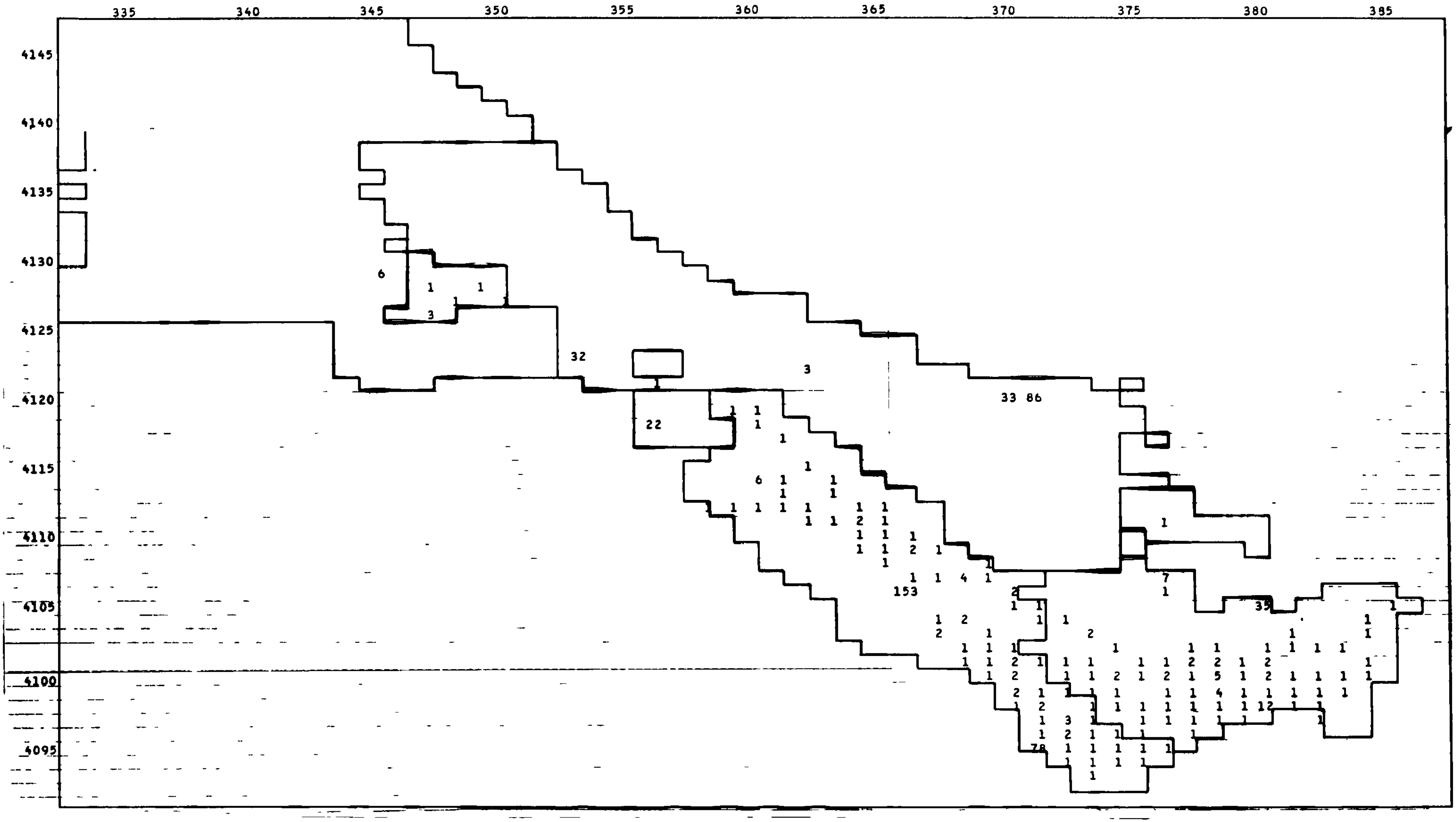

Figure 13 - Daily summer emissions of solid particulates in Peninsula, Virginia   Each unit corresponds to 13565 grams

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